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Exclusive $B \to \pi\ell^+\ell^-$ and $B \to \rho\ell^+\ell^-$ decays in the universal extra dimension

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We investigate the influence of the universal extra dimension on the branching ratio in the $B \to \pi(\rho)\ell^+\ell^-$ decay. Taking $1/R \sim \{200–1000\}$ GeV with one universal extra spatial dimension, which is consistent with the experimental data for $\mathcal{B}(B \to X_s\gamma)$, $\mathcal{B}(B \to K^*\mu^+\mu^-)$ and the electroweak precision tests, we obtain that for both (μ, τ) channels the branching ratio strongly depends on the compactification radius $1/R$.

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I. INTRODUCTION

The standard model (SM) has been a successful theory in reproducing almost all the experimental data about the interaction of gauge bosons and fermions. However, the SM is not regarded as a full theory, since it cannot address some issues, e.g., gauge and fermion mass hierarchy, matter-antimatter asymmetry, number of generations, and so on. For these reasons, the SM can be considered as a low energy manifestation of a fundamental theory.

The extra dimension model [1] is one of the candidates trying to shed light on some of those issues. It can be categorized in terms of the mechanism of new physics (NP) where the SM fields are constrained to move in the usual three spatial dimensions (D_3-brane) or can propagate in the extra dimensions (the bulk). The latter can be categorized as nonuniversal extra dimensions (NUED) and universal extra dimensions (UED). In the nonuniversal model the gauge bosons propagate into the bulk, but the fermions are confined to the D_3-brane. In contrast, the UED allows fields to propagate into the bulk. The UED can be considered as a generalization of the usual SM to a D_{3+N} brane where N is the number of extra dimensions [2]. The model introduced by Appelquist, Cheng, and Dobrescu (ACD) [3] is the simplest example of the UED where just the single universal extra dimension is considered. This model has only two free parameters in addition to the SM parameters, and those are the compactification scale R and the ultraviolet cutoff scale of UED models Λ. Since it is natural to assume that these terms are loop suppressed, they are usually ignored. The mass of the Kaluza-Klein (KK) particles is inversely proportional to R; then, at large values of $1/R$ the SM results can almost be recovered, since the KK modes, which become more and more massive, are decoupled from the low-energy SM.

Two types of studies can be conducted to explore extra dimensions. In the direct search, the center of mass energy of colliding particles must be increased to produce KK excitation states, which are supposed to be produced in pairs by KK number conservation. On the other hand, we can investigate UED effects, indirectly. The indirect search at tree level, where KK excitations can contribute as a mediator, is suppressed by KK number conservation. On the contrary, the same states can contribute to the quantum loop level where KK number conservation is broken. As a result, a flavor changing neutral current (FCNC) transition induced by the quantum loop level can be considered as a good tool for studying KK effects. The collider signatures and phenomenology of UED have been studied in Refs. [2,4,5], respectively. These studies have provided a theoretical framework to examine some inclusive and exclusive decays with the ACD model.

FCNC, CP violation, and anomalous magnetic moments of fermions [6] are indeed the most sensitive probes of NP contributions to penguin operators. Rare decays, induced by FCNC $b \to s(d)$ transitions, are at the forefront of our quest to understand flavor and the origins of CP violation asymmetry (CPV), offering one of the best probes for NP beyond the standard model, in particular, to probe extra dimensions. In this regard, the semileptonic and pure leptonic B decays and $\bar{B} - B$ oscillation have been studied with the UED scenario [4–12]. They found that the inclusive and exclusive semileptonic and pure leptonic decays are sensitive to the new parameter coming out of the one universal extra dimension, i.e., the compactification scale $1/R$.

New-physics effects manifest themselves in rare decays in different ways: NP can contribute through the new Wilson coefficients or the new operator structure in the effective Hamiltonian, which is absent in the SM. Also, NP may modify the SM parameters such as masses and Cabibbo-Kobayashi-Maskawa (CKM) matrix elements. A crucial problem in the new-physics search within flavor physics in exclusive decays is the optimal separation of new-physics effects from uncertainties. It is well known that inclusive decay modes are dominated by partonic contributions; nonperturbative corrections are, in general, much smaller [13]. Also, ratios of exclusive decay modes such as asymmetries for $B \to K(K^*, \rho, \gamma)\ell^+\ell^-$ decays

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